How to Improve the Efficiency and Quality of Clinical CNS imaging at 1.5 and 3T with Parallel Imaging Techniques

Meng Law MD MBBS FRACR

Assistant Professor of Neurosurgery and Radiology
New York University School of Medicine
NYU Medical Center, MRI Department
New York, New York

Upon completion of this talk, participants should be able to:

1. Understand the basic principles of parallel imaging
2. Recognize the advantages of brain and spine imaging
3. Recognize and avoid related artifacts and limitations of parallel imaging
4. Recognize current limitations with high field MRI
5. Appreciate the synergistic effect of combining parallel imaging with high field.
6. Appreciate some of the advanced neuro-applications of parallel imaging

The first aim of this presentation is to describe the basic principles of parallel imaging from the physical acquisition of phase and frequency encoding gradients to the utilization of multiple coils to assist with spatial signal encoding. The simultaneous acquisition of MR imaging signals with multiple receiver coils has inherent advantages for brain and spine imaging.

The major advantages are decreased acquisition times, increased spatial resolution, increased temporal resolution, increased spatial coverage, improved single shot imaging, improved contrast in inversion recovery sequences. Like high field imaging, it translates into usable imaging "currency" which can be traded depending on the clinical application and setting. Multi-channel, phased-array imaging therefore allows the radiologist considerable flexibility in choosing between increased spatial resolution, increased coverage, increased SNR or decreased imaging acquisition times. Examples of improved efficiency and quality in imaging protocols are provided.

There are however also some artifacts and limitations associated with parallel imaging, depending on which of the two primary methods are being employed. The first method undersamples k-space and uses an "unwrapping" technique (SENSE, ASSET, SPEEDER) and the second method again undersamples k-space but "fills in missing lines of k-space" using coil sensitivity profiles (SMASH,GRAPPA). Therefore, using an "unwrapping" technique, with increasing acceleration factors, an "unwrapping" artifact is sometimes seen within the reconstructed image. Recognition of this artifact will allow the

radiologist to reduce the parallel imaging factor or switch the phase and frequency encode directions to reduce the artifact over the region of particular interest.

Given this parallel imaging technology, the question of how many channels and how fast we can acquire images in the clinical setting arises. Unfortunately, as Ohliger et al. demonstrated, signal to noise (SNR) actually decreases with increasing acceleration factors. However, this SNR can be salvaged by scanning at higher magnetic field strengths (Bo) and in more than one direction (x and y axes). Three Tesla (3T) clinical systems are widely installed and 7T and 8T human research systems are in use. However, although measurements on high field systems have shown increased SNR, there is also increased artifact conspicuity (susceptibility artifact, dielectric effect and geometric distortion), increased specific absorption rate (SAR) and in some instances decreased contrast to noise (CNR), particularly with T1-wieighted imaging at high field.

The combination of parallel imaging with high field imaging appears to have a positive synergistic effect at a basic physics level which can improve the efficiency and quality of clinical CNS imaging. The combining of signal and RF pulses from multiple smaller coils allows reduction of gradient-driven Fourier encoding. So to achieve the same signal intensity, instead of the amplification of signal, susceptibility and SAR from gradient-driven Fourier encoding from a single coil, susceptibility and SAR issues encountered with high field imaging can theoretically be reduced with the higher encoding efficiency capability of parallel imaging. Improved homogeneity and sensitivity from the multi-coil design will also reduce geometric distortion seen with echo planar imaging at high field. The shorter sequences will allow the addition of more sequences in the clinical protocol, so that for T1-weighted imaging as an example, 3-4 difference sequences can be acquired instead of two. Magnetization-prepared T1 (MPRAGE/SPGR) and/or T1 Inversion Recovery (FLAIR) sequences can be acquired pre-contrast for maximal gray-white contrast and to optimize the conspicuity of enhancement from the T1 shortening of gadolinium, a turbo spin echo or fast spin echo (TSE/FSE) sequence can be acquired following contrast administration.

Finally, parallel imaging also has the potential to dramatically benefit EPI sequences used in diffusion-weighted imaging, diffusion tensor imaging, perfusion imaging and BOLD functional MRI by decreasing acquisition times and reducing susceptibility effects by decreasing the echo time (TE) and echo train length (ETL) in multi-echo sequences. It also has application in other advanced MRI techniques such as MR spectroscopy.

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